Study of Moisture Removal Rate for Liquid Desiccant De-Humidification System integrated with VCRs

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Abstract

The performance of Liquid Desiccant De-Humidification System (LDDS) combined with vapour compression refrigeration system (VCRS) has been experimentally investigated. LDDS is used in order to enhance outdoor quality of air by extracting the moisture from humid air and VCRS deals with sensible cooling of air. The system performance has been enhanced by proper mixing of outdoor air with $CaCl_2$ as a desiccant in cellulose pads dehumidifier. In this study, Moisture removal rate MRR is evaluated as an integral parameter for the investigation of the performance of de-humidifier

1. INTRODUCTION

Jain et al. [1] investigated the LD system by incorporating a double pass heat exchanger from air to LD hear & mass transfer for reducing carryover. The result showed that LiCl performed better than $CaCl_2$ in dehumidification performance. Bergero and Chiari [2] examined performances of a hybrid air-conditioned module using LiCl as a desiccant. A SIMULINK calculation program was designed for simulating the system under steady-state conditions and found measurable energy saving with in a specific operating condition. Gao et al. [3] investigated an experimental study de-humidifier which is partially cooled and concluded that the effective de-humidification and water vapors removal rate can be increased using low temperature cooling water. Das and Jain [4] carried out experiments on different hygroscopic membranes using LiCl in which a wicking material was sandwiched and concluded that polypropylene membrane showed vapors flux up to 1300 g/m^3. Das and Jain [5] fabricated five different membrane contactors and validated two-dimensional steady state mathematical model with experimental values by using LiCl as a desiccant. They suggested the effects of membrane characteristics, contactor design, fluid flow rates, ambient condition and desiccant concentration were studied for the performance of contactors. Keniar et al. [6] investigated the feasibility of a solar regenerated liquid-desiccant system to reduce the specific humidity from an office space and suggested that a reduction in 10% of indoor relative humidity was observed with the system. Li et al. [7] studied a Dynamic modeling of a liquid desiccant dehumidifier based on the principles of heat and mass transport wherein the spatial fluid differentials are defined and concluded that the proposed model performs well in experimental validation and is implemented in future control design and analysis of fault detection application. Haung et al. [9] investigated the liquid desiccant dehumidifier (IMDD) setup with internally cooled membrane for air-conditioning, in which the mass and heat transfer aspects were studied and come up with the conclusion that the $Nu_{c,fe}$, $Sh_{c,fe}$ and $Nu_{c,s}$ for such systems are about 2% to 3% lesser than the AMLDD approach. Longo and Gasparella[10] studied experimentally the measurement of thermo physical properties of desiccant comprises KCOOH including concentration of salt proportion from 0.6 to 0.8 in temperature from 1˚C to 80˚C. They concluded that the same desiccant stated above exhibits conductivity of 25% to 35% lesser than that of H_20 and dynamic viscosity 4-30 times greater than water. Several researchers had experimentally tested the liquid desiccant cooling system with different desiccants and a mixture of dehumidifier desiccants. Yet no work has been conducted on the hybrid dehumidifier packaging of cellulose pads having variable aspect ratio.

2. EXPERIMENTAL SETUP

The schematic layout of the system is shown in figure1. In dehumidifier, after passing through it the liquid desiccant adsorbs moisture from the surrounding air. After the moisture is absorbed, liquid desiccant is extracted and stored in dehumidifier tank. It is then regenerated in regenerator in order to get the original state of the diluted liquid-desiccant solution. The diluted liquid-desiccant solution coming from dehumidifier tank passing through the heat exchanger is pumped to the heater, where its temperature is raised around 60℃ and after that the hot desiccant solution is sent to regenerator in which its losses the moisture to the surrounding air passing through it and regenerated solution (concentrated form) is collected in the regenerator tank. Upon going through the heat exchanger, this solution gets slightly cooled and then pumped again to the dehumidifier, and the process continues. The dehumidified air at the dehumidifier outlet is sent to the VCRS for cooling, thus the cool dehumidified air is collected at the VCRS outlet. Unit output is studied at varying air inlet conditions such as air temperature and air humidity. With different air temperatures, air heater is used in a duct before entering air in a dehumidifier and after air heater, humidification chamber is used to achieve different humidity levels.

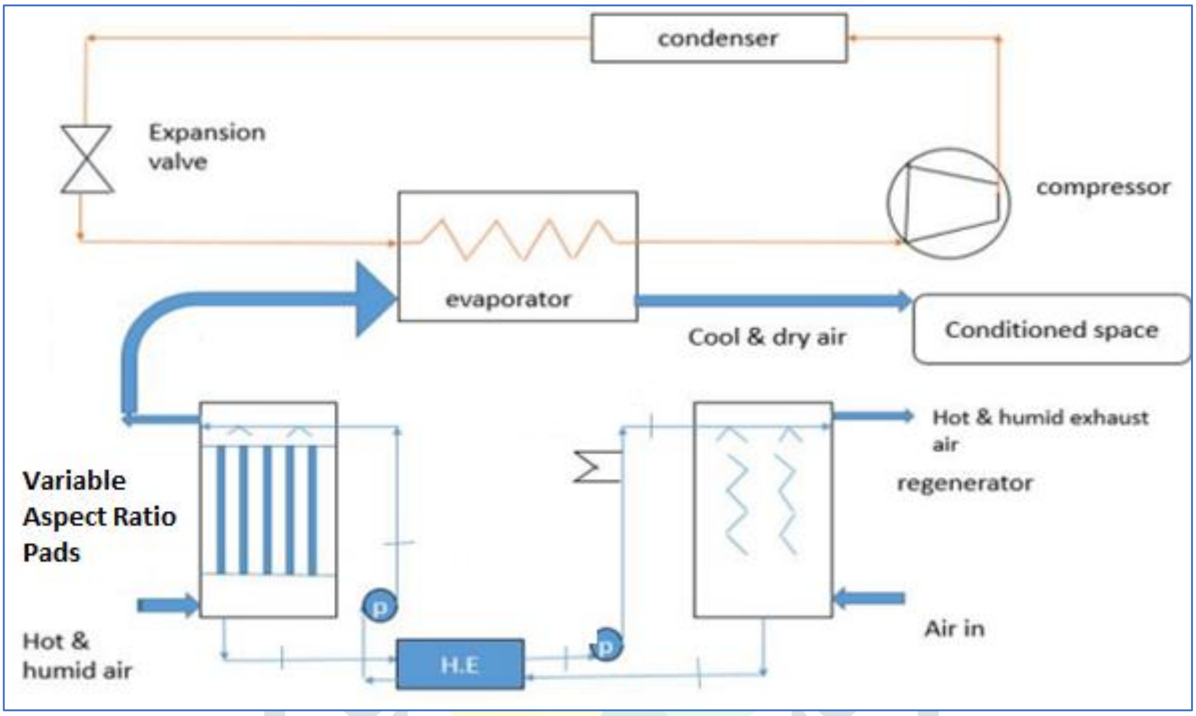

Figure 1: Schematic Layout of The Proposed System

3. EXPERIMENTAL DATA ANALYSIS

The Performance of a liquid-desiccant de-humidification device combined with the vapour compression cooling (VCRS) system has been investigated based on moisture removal (MRR)

3.1 Moisture Removal Rate (MRR):

3.1.1 The Moisture removal rate(MRR) is defined as, rate at which moisture is absorbed from inlet air and is calculated from equation (1) given by

$$MRR = m_a(w_2 - w_1) \ldots \quad (1)$$

Where w_1s absolute humidity of air at inlet; w_2 represents absolute humidity of outlet air and m_a is a mass flow rate of air at inlet.

3.1.2 Mass flow rate of the air at inlet is calculated from equation (2) as

$$m_a = \rho A v \ldots \quad (2)$$

Where "ρ" is the air density; A: Area of the column and v= Velocity of air.

3.1.3 The density of air varies with respect to pressure and temperature, so it is calculated by using ideal gas equation (3) as

$$\rho = \frac{P}{R_{spec}\,T} \ldots \quad (3)$$

Where p is the atmospheric pressure; R_{spec} as specific gas constant and T is the temperature of air.

4. RESULT AND DISCUSSION:

During testing, the flow rate of $CaCl_2$ is retained at 8 L/min at inlet to the dehumidifier and the air flow rate at the inlet is maintained at 2.05 m/s with the average temperature of the dehumidifier solution which has been preserved at different locations between 25°C and 50° C.

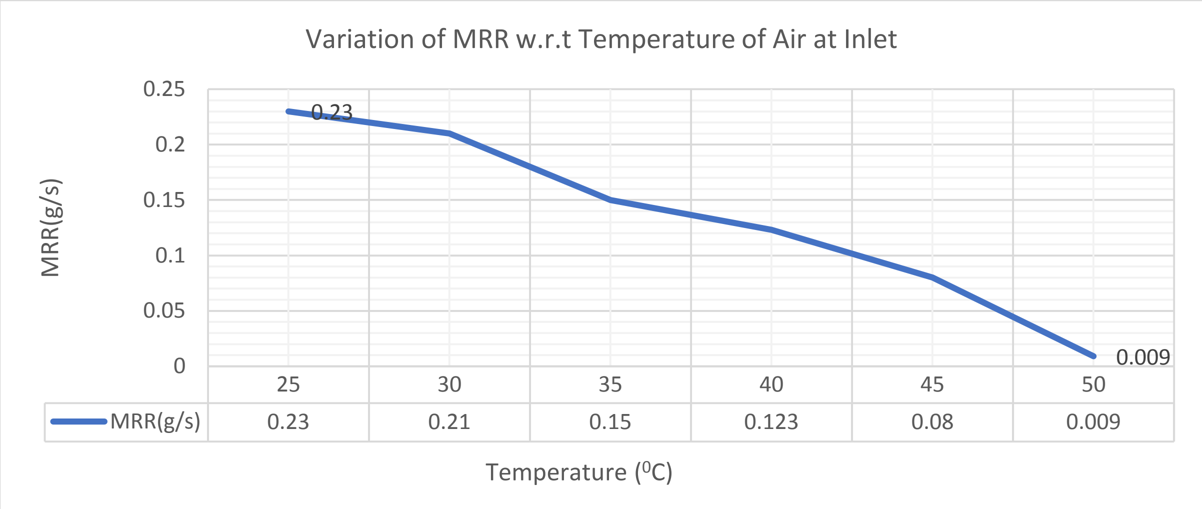

Figure 2: MRR v/s Inlet AIR Temperature

In the current analysis, the performance of a liquid-desiccant de-humidification device combined with (VCRS) vapor compression Refrigeration system has been investigated which comes to the conclusion that the MRR decreases from 0.23 to 0.009g /s when the temperature of the inlet air ranges from 25 °C to 50 °C by maintaining a constant inlet air humidity ratio of (8g)⁄(kg dry air).

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